[10191/822]

DEVICE AND METHOD FOR CONTROLLING A GENERATOR

FIELD OF THE INVENTION

The present invention relates to a device and a method for controlling a generator, for example, a three-phase generator that can be driven by an internal combustion engine in a motor vehicle.

BACKGROUND INFORMATION

At the present time, claw-pole generators are customarily used to produce the electrical power required in a motor vehicle. These claw-pole generators are three-phase generators whose output current is rectified using a diode bridge. The rectified current is then used to supply the electrical loads of the vehicle and to charge the battery.

Such a three-phase generator includes a field coil through which field current flows. The field current is regulated with the aid of a voltage regulator so that the output voltage of the generator is approximately constant independently of the rotational speed of the generator. The level of voltage at which the regulator is set is customarily selected so that it is optimally suited for charging the battery. Depending on various conditions, the voltage is between approximately 12 and 14.5 V.

In vehicle electrical systems with a large number of loads, there is the problem that a 12-V system is not adequate for the supply of power. In particular for the supply of loads requiring a higher voltage than 12 V, there are conventional methods by which the generator is regulated at least temporarily to higher voltages such as 40 V, for example. This higher voltage is then made directly available to the load in question. The lower voltage required for the supply of the vehicle electrical system or for battery charging is derived from the higher voltage with the aid of a DC-DC converter. Since, in addition to power transistors, diodes and capacitors, conventional DC-DC converters also require

EL169611340US

inductive components, they are relatively expensive. This applies to transformer (potential-free) converters with a transformer and filter choke and to non-floating choke transformers with a storage choke. Such a generator control with a DC-DC converter is described in European Patent No. 0 325 520.

SUMMARY OF THE INVENTION

The devices according to the present invention and the method according to the present invention for the control of a generator have the advantage that they can also be used with a conventional generator. In such a conventional generator, particularly a claw-pole generator, it is possible to adjust voltage to a vehicle electrical system with a higher voltage level, e.g., approximately 42 V. This voltage adjustment is also possible as long as the output voltage of the generator in the lower rotational speed range with conventional field current regulation is lower than 42 V. In one embodiment of the present invention, no supplementary chokes are required in this connection, since the stator inductors already present in any event are used as storage chokes. In an advantageous manner, this can result in lower system costs and reduced space requirements.

These advantages are obtained by connecting an additional circuit arrangement to the rectifier bridge of the generator via which the rectifier bridge can be short-circuited for brief periods of time. This results in the generator being boosted. As long as the flow of power from the generator to the battery is interrupted, the power generated is stored temporarily in the stator inductors of the generator. This results in an increase of the so-called phase voltage. In another embodiment of the present invention, the short-circuiting and the re-interruption of the electrical connection of the rectifier bridge take place using a controllable power transistor in such a way that the output voltage of the generator that can be picked off at the

rectifier bridge is increased to values amounting to approximately 42V.

In another embodiment of the present invention, the circuit arrangement with which the rectifier bridge can be short-circuited includes, in addition to the power transistor such as an MOSFET, a diode and a capacitor which are connected in such a way that the diode prevents the battery or the vehicle electrical system from being short-circuited. The capacitor is connected in parallel to the battery and, in an advantageous manner, smoothes the output voltage which can be drawn off.

According to another embodiment of the present invention, the booster transistor can be eliminated if a fully controlled rectifier bridge is implemented with controlled circuit breakers; a higher efficiency of the total system can then be obtained in an advantageous manner, since the forward power losses are lower with a proper selection of the circuit breakers than in an uncontrolled rectifier bridge constructed with diodes. In an advantageous manner, MOS field effect transistors can be used as controlled circuit breakers.

If a circuit breaker is additionally used instead of a freewheeling diode, forward power losses can be further reduced; this applies in particular to a case in which the circuit breakers are embodied as MOS field effect transistors. It is particularly advantageous that reduction of the number of components and an increase in the efficiency of the overall arrangement can be achieved in comparison with conventional arrangements.

<u>BRIEF DESCRIPTION OF THE DRAWINGS</u>

Figure 1 shows a first embodiment of a device according to the present invention.

Figure 2 shows a second embodiment of the device according to the present invention.

Figure 3 shows a third embodiment of the device according to the present invention.

Figure 4 shows a fourth embodiment of the device according to the present invention.

DETAILED DESCRIPTION

As shown in Figure 1, generator G (e.g., a claw-pole generator) includes stator inductors L1, L2 and L3 and resistors R1, R2 and R3 which represent the winding resistors. The generator produces phase voltages US1, US2, US3 which are formed from synchronous generated voltages U1, U2, U3 and the voltages at resistors R1, R2, R3 and stator inductors L1, L2, L3. These voltages result in currents I1, I2, I3, which are rectified via diode bridge DB and in generator output current IG which serves to supply the vehicle electrical system loads.

Generator G is controlled in the customary manner using a voltage regulator R, which regulates field current IF through field winding F in such a way that a specifiable voltage is obtained. Input signals E, such as various voltages and/or currents and/or the generator rotational speed, are supplied to voltage regulator R. Voltage regulator R is capable of emitting output signals A with the aid of which switches or the like can be actuated, for example.

A circuit arrangement SCH including a transistor T, a diode D and a capacitor C is connected to generator G. The circuit arrangement SCH makes the generator control according to the present invention possible in that transistor T, which is an MOS field effect transistor connected parallel to diode bridge DB, for example, short-circuits diode bridge DB from time to time. In the exemplary embodiment, transistor T is made conducting or non-conducting using a pulse width modulation stage PWM, which is integrated in voltage regulator R. The pulse frequency of transistor T is in the medium frequency range and is determined by pulse width modulation stage PWM.

This pulse width modulation stage does not necessarily have to be integrated into voltage regulator R, but rather it can, for example, be constructed as a separate stage or integrated in the electronic control unit of the vehicle. Other controls of transistor T are also conceivable.

Brief short-circuiting of diode bridge DB with power transistor T causes the flow of power from generator G to battery B to be interrupted. This makes boosting of the generator possible. In this connection, power is stored temporarily in stator inductors L1, L2 and L3 of generator G. Diode D1 prevents current from flowing back and short-circuiting and discharging the downstream electrical system or battery B. If transistor T blocks, the power stored in the stator inductors is released in the form of induced voltages which are combined with the respective synchronous generated voltages U1, U2 and U3. This results in a higher output voltage of the generator. An output voltage of 42 V can be set by suitable variation of the conduction and blocking duration; 42 volts charging voltage corresponds to 36 volts rated voltage. Capacitor C at the output of circuit arrangement SCH serves to smooth out the pulsed output current. In other respects, circuit arrangement SCH may be designated as a generator step-up converter.

If the generator control is to take place using circuit arrangement SCH so that a voltage present at the output of circuit arrangement SCH which is substantially increased in relation to the conventional generator voltage and is 42 V, for example, the conventional vehicle electrical system must be supplied using a DC-DC voltage converter. Electrical system loads to be supplied with higher voltage, a windshield heater R4, for example, can be directly connected to the 42 V via a switch S1. Loads R5, on the other hand, can be connected to 12 V via switch S2. Each voltage level has a separate battery, which are identified in Figure 1 as B42 and B12.

In the design of the total system it must be taken into account that diode bridge DB should be designed so that it is suitable for 42 V. Also generator G must be designed so that an output voltage of 42 V is handled without problems. The voltage regulator or pulse width modulation stage PWM must be designed in such a way that necessary control signals can be generated. In a microprocessor-controlled system, the control signals can be supplied by the microprocessor which may also be the electronic control unit of the internal combustion engine.

Figures 2 and 3 show two additional exemplary embodiments according to the present invention in which the field winding and the voltage regulator and the second voltage level, which are shown in Figure 1, are also basically present; however, they are not shown in detail. In both exemplary embodiments, rectifier bridge BD has been replaced by a fully controlled bridge with six circuit breakers, transistors T1 to T6, for example. Diode D1 serves as a freewheeling diode which must be considered a component of the fully controlled bridge and is connected to capacitor C. In the exemplary embodiment shown in Figure 3, the freewheeling diode has been replaced by an additional transistor T7 which is also a component of the fully controlled bridge.

The exemplary embodiments shown in Figures 2 and 3 illustrate two options for voltage adjustment, for a claw-pole generator to a higher electrical system voltage, for example, which are to be understood as a measure according to the present invention. The mode of operation of these circuits can be explained as follows:

A simultaneous activation of the six circuit breakers or transistors T1 to T6 of the fully controlled bridge circuit brings about a boost of generator G. MOS field effect transistors, for example, can be used as circuit breakers. During the phases in which circuit breakers T1 to T6 are

conductive, power is temporarily stored in stator inductors L1, L2 and L3 and is released in the blocking phase of the transistors and results in an increase in phase voltages US1, US2 and US3. This causes generator G, which is driven by a shaft of an internal combustion engine, to make a higher voltage available for the production of an electrical system voltage level of 42 V, for example, particularly in the lower rotational speed range. Diode D1 of the exemplary embodiment shown in Figure 2 prevents battery B42 from also being short-circuited and discharged during the conducting phase of circuit breakers or transistors T1 to T7.

In the exemplary embodiment shown in Figure 3, an additional circuit breaker, an MOS field effect transistor T7 is used instead of a diode. This switch is controlled in such a way that it has its blocking phase during the conducting phase of the transistors of the bridge circuit and has its conducting phase during their blocking phase. This method corresponds to a synchronous rectification. The output voltage can be regulated to 42 V by proper variation of the conducting and blocking time, for example by variation of the mark-to-space ratio, i.e., the ratio between conducting and non-conducting phases. Voltages other than 42 V can of course also be obtained if necessary.

Capacitor C at the output of the integrated step-up converter T1 to T6 and D1, T1 to T6, T7 serves to smooth out the output voltage.

The six circuit breakers (field effect transistors) are preferably controlled by pulse width modulation; however other control methods are possible. The deadbeat principle or a pulse sequence modulation can be considered as possible control methods. Basically, conventional components such as MOS field effect transistors, insulated gate bipolar transistors (IGBT) or bipolar transistors can be used as circuit breakers. If circuit breakers are used in the bridge

circuit, it must be made certain that the switch has a freewheeling diode with an inverse-parallel connection. Since this is the case with an MOS field effect transistor as a result of the manufacturing process, this component is preferably used. If a component that does not have this body diode is used as a circuit breaker, a freewheeling diode must be used as a discrete component.

Figure 4 shows another exemplary embodiment of the present invention, in which the bridge rectifier of the generator contains three diodes D2, D3, D4, as well as three transistors T8, T9, T10. With this embodiment of the rectifier bridge, by appropriately controlling the transistors, both rectification as well as voltage increase are possible. The rectification arrangement thus represents a rectifier and a set-up converter. Using this circuit according to the present invention, a claw-pole generator having an integrated set-up converter can be provided.

By integrating the step-up converter (which functions as a DC voltage converter) into the bridge rectifier, the number of components may be reduced in comparison to the other exemplary embodiments of the present invention described above. The voltage drop at diode D1 of the step-up converter shown in Figure 2 is eliminated, making the power loss in the exemplary embodiment illustrated in Figure 4 smaller than in the exemplary embodiment illustrated in Figure 2, and thus the power efficiency is improved. If transistors T8, T9, T10 are replaced by field-effect transistors, power efficiency is further improved, since the field-effect transistors have a smaller forward power losses in comparison to the diode losses.

As in the further exemplary embodiments according to the present invention, capacitor C smooths out the rectified outlet voltage of the generator. Thus mains voltage UN, which functions to supply load L, can be tapped off, the load being

indicated symbolically for the vehicle electrical system user.